# Chapter 6
# Summary and Recommendations

## General Study Conclusions:

The overall assessment of the water, sediment and biological quality of Broad Creek and the Okatee River is summarized in Figures 6.1 and 6.2. The results of this integrated assessment clearly indicate some degradation in Broad Creek and comparatively less degradation in the Okatee River based on the benchmarks used for the various analyses. In Broad Creek, 20% of the sites sampled were clearly degraded and 53% of the sites exhibited marginal conditions. In contrast, 40% of the Okatee River sites were considered to have marginal quality overall, with the remaining 60% of the sites considered to be in good condition. Evaluation of sites based on depth and proximity to land runoff sources clearly indicated that the shallow water sites (tidal creeks and intertidal flats) exhibited more degraded characteristics than the deeper subtidal river habitats in both systems. A much greater level of degradation was noted in the shallow areas of Broad Creek compared to the Okatee River (Figure 6.2).

In general, degraded water quality was more apparent in Broad Creek compared to the Okatee River. This was due primarily to fecal coliform bacteria concentrations, and elevated nutrient and total organic carbon concentrations. The 1.3 inch rainfall overnight preceding the water quality sampling in Broad Creek, coupled with the extreme high tides that inundated more land area closer to upland sources than normal appears to have had an influence on some of the water quality results for this creek. On the day water quality was sampled in Broad Creek, fecal coliform bacteria concentrations in excess of State Shellfish Harvesting Standards were widespread, thirteen of the fifteen sites (87%) exceeded 43 colonies per 100 ml. Concentrations in all six tidal creeks were also greater than the State Standards for swimming. Biotyping of the fecal coliform samples that had *E. coli* indicated that Broad Creek had both a higher incidence of *E. coli* in the samples and a higher percentage of strains that were indicative of human sources than the Okatee River. There was also a clear association of areas with high *E.coli* counts related to human sources and obvious pollution sources (e.g. land application of treated wastewater, septic tanks) in Broad Creek. However, the majority of stations in both Broad Creek (53.3%) and the Okatee River (80%) were negative for the multiple antibiotic resistance tests used for typing probable sources. This suggests that animal pollution sources are a major contributor of the fecal coliform levels observed in both systems. At the tidal creek and subtidal river sites in Broad Creek, total phosphorus was elevated relative to other SCDHEC saltwater monitoring sites. Total organic carbon was elevated relative to other SCDHEC saltwater monitoring sites at all sites in Broad Creek and in general an order of magnitude greater than the values observed in the Okatee River. In fact, turbidity and TOC concentrations in Broad Creek were near or in excess of the maximum values seen in SCDHEC Ambient Surface Water Quality Monitoring data collected in Broad Creek from 1994-1998.

A composite water quality summary score based on State Standards and other threshold values was used to summarize the water quality data. Overall water quality in Broad Creek was scored as poor at 47% of the sites, fair at 40% of the sites, and good at only 13% of the sites. Although turbidity in the Okatee River was elevated relative to other SCDHEC saltwater monitoring sites, water quality was generally better than Broad Creek based on the composite score. Only 7% of the sites scored as poor, 33% scored as fair, and 60% of the sites scored as good.

Evaluation of sediment quality was based on the frequency of excursions of sediment quality threshold or midpoint concentrations that have been shown to be correlated with degraded benthic invertebrate communities, or direct measurement of toxicity in sediment bioassays. A basic premise of this study was that Broad Creek was more chemically contaminated than the Okatee River due to the increased urbanization found in the Broad Creek watershed. Chemical contaminant analyses of sediments clearly indicated that Broad Creek was not as chemically contaminated as was expected and the Okatee River was slightly more polluted than was originally thought. Sediment contaminant concentrations at sites in both Broad Creek and the Okatee River occurred at concentrations that have been shown to be correlated with degraded benthic invertebrate communities. Only two sites in Broad Creek and one site in the Okatee River had contaminant concentrations that exceeded sediment quality guideline midpoints for toxic effects. Overall sediment quality indicated that there were five degraded sites in Broad Creek (33%) versus only two degraded sites (13%) in the Okatee River. Four sites in Broad Creek (27 %) and nine sites (60%) in Okatee River had sediments that were marginally degraded. Six sites (40% of the sites) in Broad Creek and four sites (27%) in Okatee River had good overall sediment quality.

Elevated arsenic and lindane concentrations were major contributors to many conclusions of marginal or degraded conditions. Arsenic (As) is commonly found in the sediments of South Carolina at concentrations similar to levels found in Broad Creek and the Okatee River. The arsenic concentrations observed generally reflected the high background levels found in estuarine sediments of the southeastern U.S. and are probably not entirely due to anthropogenic inputs. Lindane concentrations were elevated in sediments in both watersheds at concentrations greater than sediment quality thresholds and midpoints for toxic effects. Lindane is a chlorinated hydrocarbon insecticide used in both agricultural and urban applications as a soil fumigant and foliar treatment on fruit and nut trees as well as vegetable and ornamental plants (Farm Chemical Handbook, 1992). Persistent organochlorine pesticides, such as lindane, may persist in estuarine sediments long after agricultural lands are converted to urban areas, adding to the toxicity potential of sediments as increased pollutant discharges occur with urbanization. This long-term persistence may explain in part both the occurrence and spatial distribution of observed degradation in Broad Creek and the Okatee River.

Concentrations of other organic contaminants, including polycyclic aromatic hydrocarbons (PAHs), were generally low, as only one site in Broad Creek had sediment quality threshold excursions for a single PAH. In general, PAH concentrations in Broad Creek and the Okatee River were lower or comparable to sediment PAH concentrations measured in pristine NOAA National Estuarine Research Reserves and Sanctuaries in South Carolina (North Inlet and the ACE Basin). Comparisons of Broad Creek sediment PAH concentrations with other suburbanized areas of SC (Murrells Inlet) indicated much lower levels in Broad Creek, possibly resulting from the land use planning restrictions placed on development on Hilton Head Island, SC, to control nonpoint source runoff. Beaufort County should continue strict land use planning and zoning requirements to help minimize water quality impacts. This should be particularly enforced on the Okatee River, due to the relatively high concentrations of lindane and arsenic, which already exists there.

The biggest difference in sediment quality observed was the apparent transition of marginally contaminated sites in Broad Creek to degraded sites. This may be directly related to increased urbanization in this area which has resulted in inputs of chemical contaminants. Most of the toxicological effects observed appear to be the result of cumulative impacts from multiple stressors rather than one individual contaminant *per se*. This is a classical urbanization effect, as previous studies (Fulton et al, 1993, 1997) have noted that urbanization is a process of both contaminant loadings, changes in hydrography and the water cycle (both surface and groundwater), and habitat loss/modification. Benthic and grass shrimp population assessments generally indicated that there were only marginal impacts observed in both Broad Creek and the Okatee River, with greatest effects observed in benthic organisms in direct contact with sediment contaminants. This suggests that environmental quality is at a point in Broad Creek where further environmental degradation may result in more pervasive impacts within this watershed. Further, this points to the importance of properly managing development of the Okatee watershed, to minimize urbanization impacts.

In general, the biological communities evaluated in this study showed no evidence of substantial degradation compared to other estuarine habitats in South Carolina with similar characteristics. Of the four types of biological assemblages considered, the benthic invertebrate communities showed the clearest evidence of a response to degraded water and/or sediment quality that was observed in either drainage system. These effects were primarily limited to a dominance by species known to be tolerant of pollution and other environmental stresses. The effects were largely limited to a few sites, including four tidal creeks (two in each system) and two intertidal mud flats (Broad Creek only). Two of four tidal creeks that showed the greatest evidence of stress were located in the uppermost (headwater) portion of each drainage system. These areas tend to be subjected to greater salinity fluctuations compared to other creeks and habitats located lower in the estuary, which may account for most of the alterations observed. In addition, alterations in impervious land surface may lead to increased freshwater loading, which may cause greater fluctuations in salinity. Low dissolved oxygen and contaminant stress may also account for some of the alterations in faunal composition observed in the Broad Creek drainage basin. The elevated contaminant levels observed in two of the intertidal flats (depositional habitats) sampled in Broad Creek probably accounts for the dominance of pollution tolerant species observed there, but the overall changes in community structure and composition were not especially severe. Although the benthic assemblages were not severely degraded at most of the sites sampled, the changes observed serve as an "early warning" ecological signal that upland activities are beginning to affect the biological resources present in the shallow water habitats of these drainage systems.

The oyster populations were the only other biota that showed some evidence of adverse effects in both drainage systems. The effects were primarily limited to evidence of cellular dysfunction and accumulation of a few metal contaminants in the oyster tissue sample. These conditions were pervasive in both Broad Creek and the Okatee River, which would suggest that the higher level of upland development in Broad Creek was not having any clear deleterious effects on oyster population health. While higher than anticipated, in our opinion, the chemical contaminant levels observed in the oyster tissue of both systems were not evidence of a major chemical contaminant loading problem. However, it does serve as an early warning signal that land runoff may be the cause of the contaminant levels observed. The poorer overall condition of the oyster beds observed in the headwaters of both drainage systems may reflect the effects of higher salinity fluctuations there, but some of these effects would be anticipated in the headwaters of many drainage systems, regardless of the surrounding upland development. Increased freshwater runoff from upland modifications to the landscape will only serve to exacerbate this situation.

In summary, a large number of environmental quality and biological condition measures were examined in both Broad Creek and the Okatee River. Although we observed differences among many of these measures, both within and between the two drainage systems, many of the environmental and biological measures appear to be consistent with other non-degraded estuarine sites that have been sampled in South Carolina, especially in the open water, subtidal portions of Broad Creek. Creek. The tidal creeks and flats showed greater evidence of stress related to both water quality and biotic condition. Because the Broad Creek watershed is more heavily developed than that of the Okatee River, contaminant levels and evidence of biotic stress were less than anticipated, possibly due to the land use planning restrictions established for Hilton Head Island development to control non-point source runoff. While the Okatee River had fewer sites that showed evidence of anthropogenic stress, some problems were noted in the headwater areas, and past agricultural practices in the Okatee River drainage may have contributed to the higher than anticipated contaminants concentrations observed.

## Recommendations:

Our primary objective in this study was to determine baseline conditions of the water, sediment and biological quality of the Broad Creek (developed) and Okatee River (undeveloped) estuaries. However, our study findings also provide an opportunity to suggest some approaches that Beaufort County and the Town of Hilton Head may want to consider in order to reduce adverse effects on the estuarine wetland habitats in these two drainage systems. These recommendations may also apply to other drainage systems in the County.

### *Bacterial Loading Problems:*

As noted in Chapter 3, we found clear evidence of increased bacterial loading from human sources in Broad Creek and some limited areas of the Okatee. There was also evidence of animal sources of fecal coliform bacteria in both systems. Possible solutions to alleviate some of these loadings are as follows:

- *Evaluate sewage treatment facilities and land disposal activities to ensure that they are not a major source of the observed fecal coliform bacteria concentrations.*

  Land application of treated effluent is the most common disposal practice on Hilton Head Island. This practice assists the recharge of underground aquifers both directly and by reducing the use of limited groundwater supplies. This treated effluent meets applicable standards at the time of final treatment. However, final treatment often takes place at a time and location different from the time and site of application. The possibility of significant multiplication and regrowth of fecal coliform bacteria in the nutrient-rich mixture prior to application needs to be investigated. Overland runoff from land application sites are prohibited by SCDHEC permits. Groundwater monitoring at the land application sites, and submittal of said data to SCDHEC, is required by permit. This existing data should be reviewed by a geohydrologist to evaluate groundwater as a potential pathway of fecal contamination. An evaluation of fecal coliform contributions from septic tanks and stormwater runoff directly to the creek and lagoon/canal systems should be further studied to quantify their contributions.

  A related question that should be examined is whether treated effluent to be land applied should be treated to Shellfish Harvesting Standards for fecal coliform bacteria, rather than the less stringent swimming Standards. If the question of potential overland runoff and groundwater contributions from land application sites as a direct source of fecal coliform bacteria to Broad Creek can be eliminated, this would not be an issue.

- *Consider options for increasing sewer hookups for those properties currently on septic tank systems, especially in the Broad Creek drainage system.*

  The results of this study show that portions of Broad Creek adjacent to high densities of septic tanks have elevated fecal coliform bacteria concentrations that show evidence of some human contribution. This suggests that fecal coliform bacteria concentrations may be lowered, and perhaps some shellfish beds could be opened, if neighborhoods on septic tanks could be connected to wastewater treatment facilities and the tile fields eliminated.

- *Evaluate Best Management Practices, including buffers, to reduce nonpoint source runoff and manage stormwater runoff.*

Nonpoint source runoff has previously been shown to be a source of fecal coliform bacteria to Broad Creek (SCDHEC, 1996). The ditches, creeks and lagoon/canal drainage systems also contribute fecal coliform bacteria even under dry weather conditions. Statewide, nonpoint sources of fecal coliform bacteria are more important than treated wastewater as a source of water quality impairment. This study has shown the added influence of stormwater runoff and upland inundation due to extreme high tides.

Nationally, studies are lacking which have verified in an integrated fashion the overall effectiveness of watershed protection strategies such as buffer width, set back distance and percent impervious surface within a watershed. All of these methods are used to formulate a *Cumulative Risk Reduction* (CRR) strategy for managing urbanization impacts within a watershed. Studies are needed which would evaluate the effectiveness of current CRR strategies employed on developed watersheds in Beaufort County such as Broad Creek. This would allow development of statistical models, which could test the importance of each risk reduction strategy in terms of bacterial loadings. While buffer width is very important, the activities permitted within buffer zones may be equally important. Studies should be conducted to evaluate current buffer effectiveness, activities within each buffer and to determine the importance of factors such as buffer width, vegetation/view corridors and wildlife corridors. Wildlife corridors may be of great importance as the majority of the fecal coliform pollution within Broad Creek and the Okatee River was negative for antibiotic resistance and may potentially be wildlife in origin. As coastal watersheds are urbanized, maintenance of a vegetated waterfront buffer zone invites/attracts wildlife to those areas. Compressed wildlife populations will tend to live in the remaining green spaces and will often use marsh habitat areas for defecation, using the terrestrial upland for feeding and nesting activities. For example, wildlife such as raccoons will defecate in the marsh and often become the primary source of fecal coliform bacteria in affected tidal creeks. It is important that buffer and green space design have wildlife corridors that lead away from the vegetated buffer areas adjacent to tidal creeks. This would allow and encourage wildlife feeding and defecation activities at a distance away from estuarine tidal creeks. While raccoons may still feed on oysters and defecate in the marsh, the location of alternative upland terrestrial food sources in wildlife corridors may ultimately reduce fecal coliform loadings from wildlife sources. Similar strategies may be employed for other wildlife sources such as deer, muskrat and birds. As stated previously, the existing groundwater monitoring well data associated with the treated wastewater land application sites should be reviewed by a geohydrologist to evaluate groundwater as a potential pathway of fecal contamination. An evaluation of fecal coliform contributions from septic tanks and stormwater runoff directly to the creek and lagoon/canal systems should be further studied to quantify their contributions. This will enable the Town and County governments to make more effective decisions on future urban development within the County in terms of wastewater disposal or treatment.

Cumulative risk reduction strategies could be effective in urban areas including reducing the amount of impervious surfaces, use of detention basins or retention ponds, BMPs for yards and lawns, the inclusion of properly designed green space corridors and the planting of trees and other vegetative cover in critical drainage areas near streams. Most of this effort could be consolidated with a countywide stormwater utility plan. This will require a substantial public education program on the importance of urban NPS runoff control and how stormwater utilities can prevent/manage environmental impacts of urban NPS runoff.

- *Increase public education related to the problems of bacterial loading from non-human sources on estuarine waters.*

Many people do not realize that much of the bacterial loading problem can come from nonpoint source runoff of fecal material from pets, domestic animals, and local wildlife such as raccoons, other small fur-bearing animals, and birds, especially seagulls and other shorebirds attracted to non-natural food sources left by humans. When these sources are located close to estuarine habitats, they can result in significant bacterial loading to small drainage areas. Ensuring that trash dumpsters located next to waterways (e.g. at boat landings, etc.) are kept closed, discouraging feeding of birds, eliminating runoff from equestrian and other domestic animal facilities, and avoiding the creation of green spaces that would tend to concentrate wildlife next to estuarine wetlands are just a few ways to reduce bacterial loading from these sources.

- *Monitor and enforce the use of marina pumpout facilities.*

Although we found no evidence that marina facilities were contributing to the bacterial loading problem observed in Broad Creek, this drainage system supports a considerable amount of boating activity, with many boats having marine sanitation devices (MSD). The Town of Hilton Head recognizes that the surface waters of Broad Creek are important economic and recreational resources. Town officials share residents concerns related to the degradation of water quality in Broad Creek as indicated by recurrent closures of areas to shellfish harvesting. They believe it directly threatens the environment and has resulted in negative economic impacts to the community. Therefore the Town of Hilton Head and its citizenry initiated an application for a No Discharge Zone (NDZ) designation for Broad Creek. Designation of Broad Creek as an NDZ would prohibit direct discharge to the creek from marine sanitation devices (MSDs) and would require disposal at a sanitary waste pumpout facility. There are presently four such marinas with pumpout facilities in Broad Creek: Palmetto Bay Marina, Wexford Lock Harbor Marina, Broad Creek Marina, and Shelter Cove Marina.

The request to have Broad Creek designated as a No Discharge Zone has been approved by the United States Environmental Protection Agency Region IV pursuant to Section 312(f)(3) of the Clean Water Act and Federal Regulation 40 CFR 140.4.

The SCDHEC Board concurred and forwarded the measure to the legislature for approval. Action on the measure is expected during the current legislative session. A strong public education campaign, combined with enforcement, would help to ensure that boaters are not part of the source of the fecal bacterial levels observed in Broad Creek. With the increased number of registered boats forecast for the state over the next 10 years, it may be wise to evaluate the need for this type of designation elsewhere in Beaufort County.

Also, with regard to pumpout facilities, SCDHEC's Office of Ocean and Coastal Resource Management works in concert with the U.S. Fish and Wildlife Service in the administration of the Clean Vessel Act Marina Pumpout Grant Program in South Carolina. This program provides for a 75/25 cost sharing between the federal government and the marina operators for the installation, maintenance, or repair of marina pumpout facilities. Through this program monies are available for the construction of new facilities, the renovation of existing facilities, the purchase of portable pumpout units, the purchase of boat-mounted pumpout facilities, and to provide operation and maintenance monies. All of these grants not only provide for pumpout facility improvements, they also provide an educational component that is designed to educate the boaters about the importance of using pumpout stations and about their locations and availability. Standardized signage is also provided under these programs, as well as a guidebook and educational programs. This grant program could provide the resources for improvements and maintenance of existing pumpout facilities or additional pumpout facilities as resident boat registration increases.

### *Nutrient Loading:*

- *Evaluate groundwater loading as a significant source of nutrient levels observed in Broad Creek.*

Total organic carbon (TOC) and total phosphorus appeared to be elevated in Broad Creek relative to the Okatee River. However, the 1.3 inch rainfall overnight preceding the water quality sampling in Broad Creek had an influence on the TOC results for this creek.

Land application of treated effluent is the most common disposal practice on Hilton Head Island. This practice assists the recharge of underground aquifers both directly and by reducing the use of limited groundwater supplies. Overland runoff from land application sites are prohibited by SCDHEC permits. Groundwater monitoring at the land application sites, and submittal of said data to SCDHEC, is required by permit. This existing data should be reviewed by a geohydrologist to evaluate groundwater as a potential pathway of excess nutrient loading. An evaluation of nutrient loading from septic tanks directly to the creek and lagoon/canal systems should be further studied to quantify their contributions.

This will be of particular importance in siting future residential developments which have golf courses with land applied treated wastewater as a focal part of development. In general, the more landward (away from sensitive tidal creek watersheds) land application sites are located, the greater the assimilative capacity of the soils and watershed dynamic for land application of treated wastewater will be, as there will be a greater buffer distance between the application site and the receiving stream. After review of existing groundwater data, additional modelling and research (monitoring and assessment) may be needed to better predict the potential impacts of groundwater loading in the landscape of this region. If impacts are observed, mitigation steps may include reductions in volumes of treated wastewater applied, further treatment of wastewater prior to land application or a combination of both methods.

- *Evaluate land disposal activities, nonpoint source, and stormwater runoff to determine their relative contributions of nutrients*

Elevated total organic carbon and total phosphorus in Broad Creek relative to the Okatee suggests development-related inputs to this system. Nonpoint source discharges to the system should be monitored for nitrogen and phosphorus loads. This study has shown the added influence of stormwater runoff due to the 1.3 inch rainfall overnight preceding the water quality sampling in Broad Creek. Studies should be conducted to evaluate current buffer effectiveness, activities within each buffer and to determine the importance of factors such as buffer width, vegetation/ view corridors and wildlife corridors. Additionally, stormwater runoff directly to the creek and lagoon/canal systems should be monitored to quantify its contributions. The Cumulative Risk Reduction (CRR) approach discussed under Bacterial Loading Problems applies to nutrient loading as well. As part of such a strategy, nutrient loading from malfunctioning septic tanks directly to the creek and lagoon/canal systems should be further studied to quantify their contributions. This will enable the city and county governments to make more effective decisions on future urban development within the county in terms of wastewater disposal or treatment.

- *Educate the public on nonpoint source runoff effects*

Research has clearly shown that reductions of nonpoint source runoff must utilize a cumulative risk reduction strategy. For agricultural nonpoint source runoff this has included methods such as Integrated Pest Management (IPM), selection of less toxic pesticides, Best Management Practices (BMPs) for tillage and soil conservation and retention ponds. Scott et al. (1999; 1992) reported that this method resulted in substantial reductions in *instream* pesticide concentrations (89-90%) for agricultural areas which utilized this approach. This will require education of farmers in Beaufort County to further develop this type of program. Similar cumulative risk reduction strategies will be effective in urban areas including reducing the amount of impervious surfaces, use of detention basins or retention ponds, BMPs for yards and lawns including amounts and types of fertilizers and lawn care products used, the inclusion of properly designed green space corridors and the planting of trees and other vegetative cover in critical drainage areas near streams. Most of this effort could be consolidated with a County-wide stormwater utility plan. This will require a substantial public education program on the importance of urban NPS runoff control and how stormwater utilities can prevent/manage environmental impacts of urban NPS runoff. This educational effort should be geared at both the new homeowner and at retrofitting existing residential areas. A review of BMPs currently used for golf courses in the region may also be appropriate, so as to evaluate and routinely (e.g. every 5 years) update these BMPs on a regular basis.

### *Contaminants:*

- *Educate the public on the likely sources of contaminants to estuarine waters in Beaufort County and ways to reduce the problem.*

The most frequently detected anthropogenic chemical contaminants were pesticides (e.g. lindane) and PAHs, with highest concentrations being measured in the urbanized Broad Creek watershed. This finding underscores the importance of reducing the sources and types of pesticides used in residential areas. Pesticides can be controlled in several ways. First and foremost, urban and agricultural areas should follow the recommended procedures described above for controlling NPS runoff. In addition, public education of the risks from pesticides is equally important. Homeowner associations may wish to annually or semi-annually meet with Clemson Extension Service personnel to review recommended pesticide and fertilizer application treatments for urban pest controls such as termites, fire ants and mole crickets. When possible, natural biological treatments (e.g. microbial pesticides or natural predator treatments) are preferred over traditional chemical treatments, and nonpersistent pesticides are preferable over persistent pesticides. In addition, in critical buffer zones around tidal creeks, further consideration should be given to the use of the least toxic and least persistent pesticides for pest control in these areas.

Control of PAHs from roadways and marinas is also a critical issue. The marina association in Beaufort County should be encouraged to continue their pro-active risk communication approaches in communicating environmental boating issues to the public. Consumer education on the importance of pumpout facilities for bacterial pollution control; proper fueling procedures, operation and maintenance of outboard engines to reduce PAH pollution in waterways; recommended antifouling paints; and the higher fuel efficiency and low pollution emissions of new outboard engine technology should be among the important messages communicated to the public. In addition, marinas should be encouraged to develop their own environmental friendly marina standards for operations above those required by current local, state and federal law. Development of A “Bay Safe Marina” Program by marina operators which would allow participating marinas meeting those operational standards set forth by the Beaufort County Marina Association to display and advertise that they are a "Bay Safe Marina" could also be considered. This would include development of stricter standards for pumpout facilities, fueling operations and boat yard work. Similar programs could be developed by farmers (e.g. "Bay Safe Farms") and residential developers. Inclusion of the public in developing these "Bay Safe" programs will be vital to their success.

### *Water Management:*

- *Control freshwater inflow in headwater areas of estuarine drainage systems.*

As noted in Chapter 5, most marine and many estuarine species are not well adapted to endure large fluctuations in salinity conditions. When salinity levels get below 10 ppt, many species, including oysters, cannot survive well, especially if those conditions occur frequently or for extended periods of time. The effects of freshwater runoff are more pronounced in small drainage systems and the upper ends (headwaters) of larger drainage systems, which often receive the greatest loads of freshwater runoff compared to areas more seaward and are often larger and therefore experience less dilution than the headwater areas. In order to avoid the adverse effects of large fluctuations in salinity related to freshwater runoff from rain events, Beaufort County should look at the best approaches to increase retention of excess water from developments and improved regulation of water from the retention ponds to create more stable flow conditions where feasible. This might be achieved by creating larger retention ponds with active flow control devices. It should be noted that the extensive network of retention ponds in the Hilton Head Island area might be one reason that we did not observe a higher incidence of chemical contaminants and related adverse effects in Broad Creek compared to other highly developed estuarine systems that have been studied elsewhere in the state.

### *Future Monitoring:*

- *Continue to evaluate conditions at periodic intervals.*

We strongly urge the county to continue to monitor environmental and biological conditions in these two drainage systems, and increase their efforts to evaluate estuarine conditions elsewhere. This study provides an excellent baseline assessment of the two estuaries studied that can be used for comparison in future studies. The frequency of sampling may vary dependent on the variables considered. For example, water quality conditions are generally less expensive to monitor than sediment quality and biological condition, which tend to be more stable and would not need to be monitored as frequently. As part of the water quality monitoring effort, future assessments should include monitoring directed at identifying contents of the effluents from retention ponds, especially bacterial levels, nutrient levels, and dissolved oxygen conditions. Analyses of effluents from the retention ponds should encompass significant rainfall events. Evaluation of runoff from land application sites and potential septic tank contributions are other areas for potential study.

We recommend that monitoring be conducted a minimum of every five years for water and sediment quality. This could include some biological monitoring as well, but a large biological monitoring effort could probably be limited to less frequent time periods (e.g. every 10 years or every 5 years for selected components such as the oysters and possibly the benthos for selected sites). The special studies noted above (e.g. retention pond effluents, groundwater, monitoring areas receiving discharges from permitted disposal activities) should be implemented as soon as feasible and should be done at more frequent intervals than the larger scale surveys.

- *Establish a Citizens Watch Program*

Citizens Watch and Water Watch Programs have proven to be effective in other areas and give the interested community members a sense of ownership and purpose. These programs have been quite varied in scope, and vary from simple reporting of violations in wetland areas to active participation in monitoring conditions. Beaufort County and the Clean Water Task Force should evaluate programs that have been implemented in other areas and resolve what might work best for their situation. At the very least, an advertisement campaign should be initiated to educate the general public on the existing programs that have been established by the SCDNR and SCDHEC (e.g. SCDHEC Water Watch, SCDNR Operation Game Thief, etc) and promote their active participation in reporting violations.

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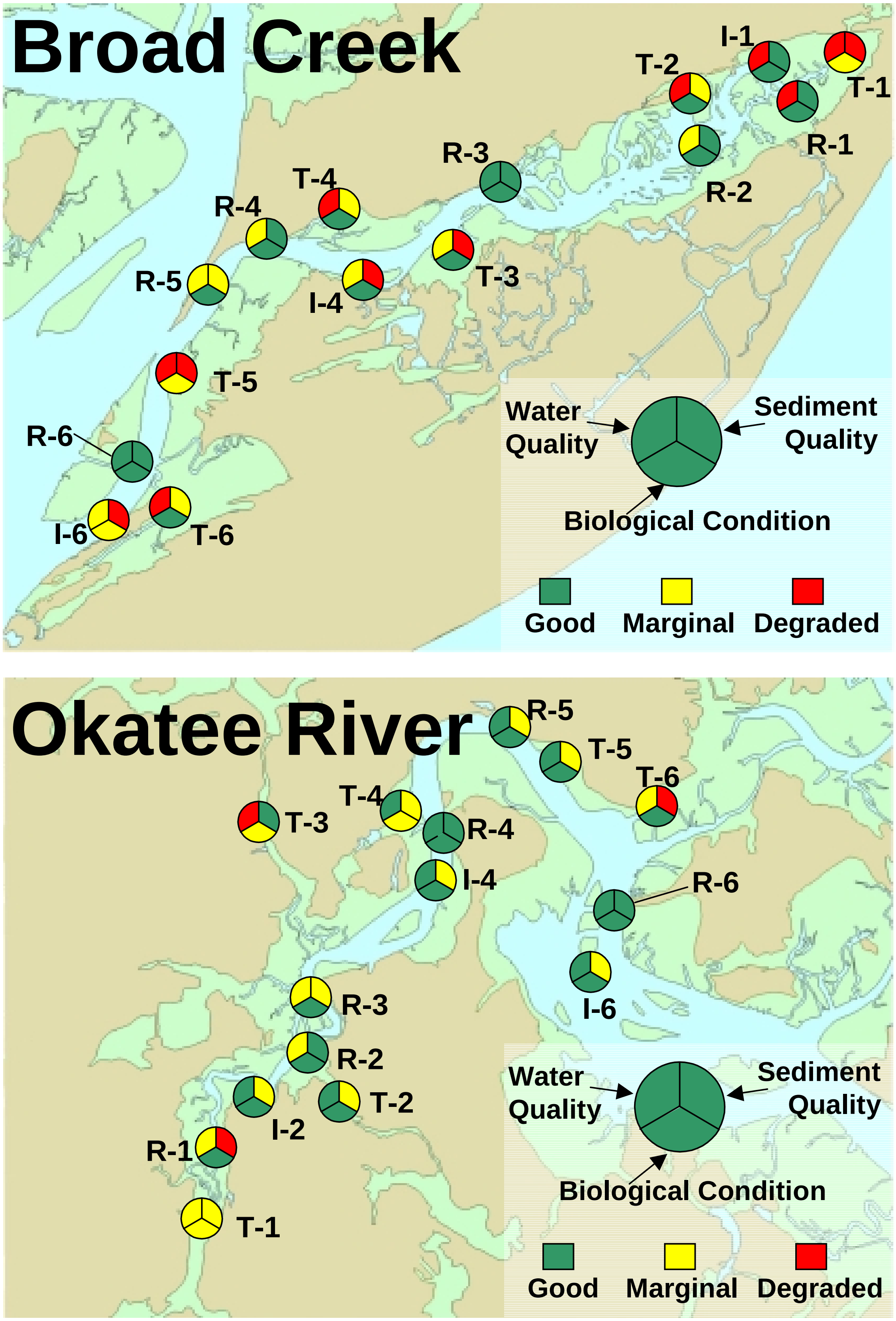


**Figure 6.1** Summary of overall site conditions based on water quality, sediment quality, and biological condition.

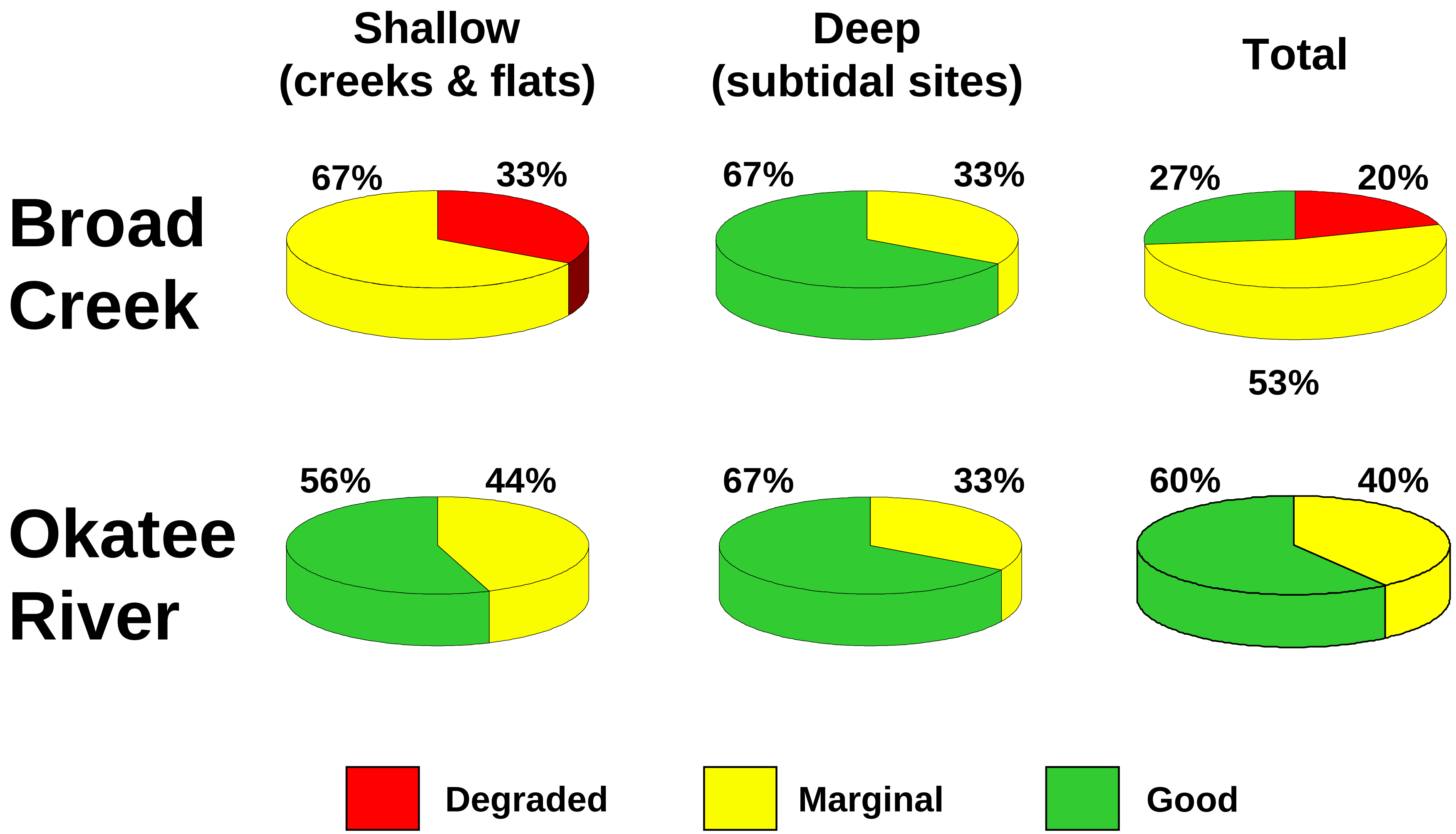


**Figure 6.2.** Summary of overall conditions based on water quality, sediment quality, and biological conditions.